Available online at www.sciencedirect.com
ScienceDirect
Procedia Social and Behavioral Sciences
Procedia - Social and Behavioral Sciences 174 (2015) 4018 – 4025

INTE 2014

3-dimensional analysis of asynchronous motor with finite element method

Sevcan Aytac Korkmaz[a], Hasan Kürüm[b]

[a] Engineering Faculty, Department of Electrical-Electronic Engineering, Firat University,23100, Elazığ, Turkey
[b]Engineering Faculty, Department of Electrical-Electronic Engineering, Firat University,23100, Elazığ, Turkey

Abstract

In this article, it will be focused on 3-dimensional analysis of an asynchronous motor with finite element method. Analysis of finite element of an asynchronous motor was performed with the help of a program developed by Maxwell 3D software program. Analysis of an asynchronous motor was conducted by calculating magnetic flux density B, current densities and as a result moment value.

Peer-review under responsibility of the Sakarya University

Keywords: Induction Motor; Finite element Method; Maxwell 3D

1. Introduction

The two-dimensional and analytical solutions not provide enough solutions. Particularly in different type of geometry or nonlinear models cases, at magnetic saturation, end-coil designs, effective fringing field simulators three-dimensional solution gives more accurate forecasts (Chari, and Silvister, 1970). So Maxwell and similar 3 dimensional programs are more suitable for magnetic analysis (Zienkiewicz, Lyness and Owen, 1977). Analysis of finite element of an asynchronous motor was performed with the help of a program developed by Maxwell 3D software program. Analysis of an asynchronous motor was conducted by calculating magnetic flux density B, current densities and as a result moment value.

2. Asynchronous Motor

Aspects of being robust, requiring little maintenance, the low cost, not being affected by environmental conditions and their power per unit volume Asynchronous motors are superior to other motors and can be used in almost every

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: sevcanaytackorkmaz@gmail.com

Peer-review under responsibility of the Sakarya University
doi:10.1016/j.sbspro.2015.01.1149

field. Motor analyzed have 18 stator and 22 rotor risers as shown in Fig 1. The air gap between stator and rotor is 0.5mm. Air gap=0.5mm

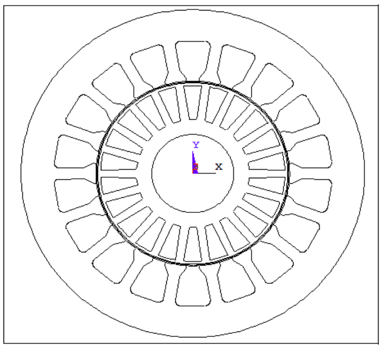


Fig.1. Front view of the motor

2.1. *Winding chart of stator*

Investigated three-phase asynchronous motor winded as half-mold and winding chart shown in Fig. 2. Motor star was connected. Enameled copper conductors have diameter 2*0.55mm and winded as 47 windings.

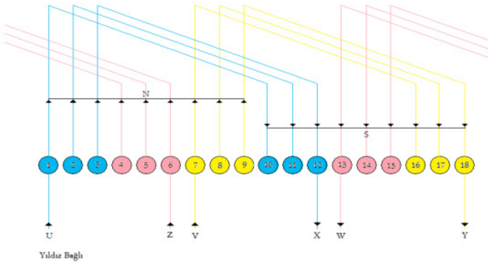


Fig. 2. Winding chart of stator

Diameter of wire: 2*0.55mm   Number of windings: 47 windings

2.2. *Identification of materials used in the motor*

In the analysis of motor 5 materials were used. which is Air, Silicon plate (stator and rotor), Copper stator winding, Aluminum rotor winding, Rotor shaft.

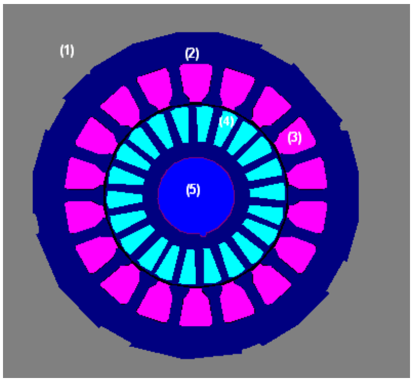


Fig.3. The geometry of the motor according to material types

3. Finite Element Method

In finite element method initially solution area is divided small triangle elements. In numerical calculation it is essential and expresses approximate solution (Silvester, Cabaya and Browne,1973). The two-dimensional analysis of elements divided into triangle based on areas and the three-dimensional analysis based on volumes. So to be uncomplicated to calculate area and volume, it is essential to divide elements which are not disrupting the boundaries of the solution. Triangle and tetrahedron areas are most preferred for providing curved boundaries. To increase the accuracy of the solution it is important that division of solution area of elements to be as small as possible and areas where potential changes in vector is more to be divided smaller elements.

3.1. The Theory of Finite Element Method

$$\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}=0 \tag{1}$$

$$\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2}=f(x,y) \tag{2}$$

The finite element method is a type of Laplace Eq. (1) and Poission Eq. (2) used in solution of partial differential equations.

3.2. The Finite Elements and Rayleigh-Ritz Method

The finite element method is based on searching solution in small finite elements where it is impossible to find a potential function for all solution area because of complicated boundary conditions. For solution, all solution area is divided into same geometrical elements with the condition that shape of geometrical elements remains same (Williamson and Ralph, 1982). In this study triangle elements are used.

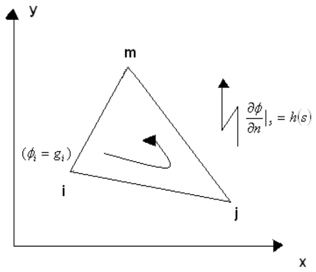


Fig.4. A triangle element

Initially a trial function is selected for solution in this method. This refers to the change in function area. First-order polynomial part of the trial function Eq. (3) provides the sensitivity for most problems:

$$\phi(x, y) = \alpha_0 + \alpha_1 x + \alpha_2 y \tag{3}$$

In this trial function, ϕ changes linearly according to x and y. If potential at edge of triangle is $\phi_i, \phi_\mathrm{j}, \phi_\mathrm{m}$, the trial function should provide these values at edge points. So the expressions below can be written:

$$\phi_i = \alpha_0 + \alpha_1 x_i + \alpha_2 y_i \quad \phi_j = \alpha_0 + \alpha_1 x_j + \alpha_2 y_j \quad \phi_m = \alpha_0 + \alpha_1 x_m + \alpha_2 y_m \tag{4}$$

N_i, N_j, N_m figure or interpolation functions are used to define the discussed trial function's edge values ($\phi_i, \phi_\mathrm{j}, \phi_\mathrm{m}$) as shown in Fig. 4.

3.3. Combination of elements

Potential function of solution must be continuous in the entire region and boundaries between the elements. Potential varies linearly within and on the sides of element of a triangle.

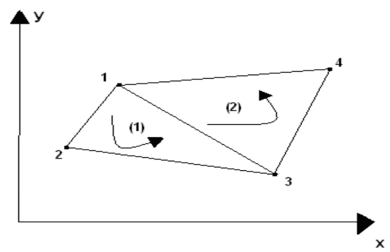


Fig.5. The combination of two triangle elements

Current may be present in some nodes due nature of the problem. In this case, the following equation system is arranged to (Chari and Silvister, 1970).

4. Three Dimensional Analysis of Asynchronous Motor

Maxwell 3D field simulator, accurate, efficient, fast and flexible program used for the solution. Maxwell 3D finite element package software is powerful tools for research, design and analysis. The two-dimensional analytical solutions not provide sufficient accuracy. Particularly in different type of geometry or nonlinear models cases, at magnetic saturation, end-coil designs, effective fringing field simulators three-dimensional solution gives more accurate forecasts (Selçuk, 2003). So Maxwell and similar 3 dimensional programs are more suitable for magnetic analysis. Especially results on the three-dimensional visual analysis of geometry of the model provide more accurate and effective comments about the system (Zienkiewicz, Lyness and Owen, 1977). For this reason, using Maxwell 3D program is important for the magnetic system designer.

4.1. Partition of asynchronous motor and data production

To avoid the problem of memory, a study in order to get fast results and ease of operation at least two coil motors, a maximum of six coils, are discussed. Despite the fact that the program works for several days it does not respond when the other windings placed. Accordingly, the necessary analysis and calculations were made. According to the finite element method, Fig. 1 illustrates an asynchronous motor after partitioned by hand, each node in the x, y, and z coordinates and node numbers that make up tetrahedron, with manual operation of partition, error control is made. If the node numbers that make up a tetrahedron, if one or more of x, y, and z coordinates incorrectly entered, it is very easy to see in this section and correct.

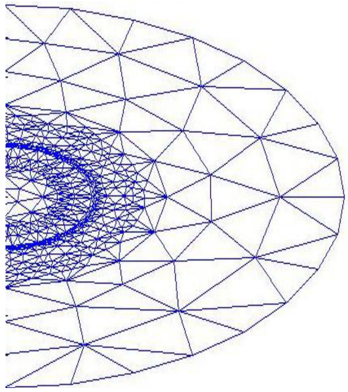


Fig.6. Manually partition of motor with Matlab.

Values of motor partitioned manually**;**

Number of nodes **=** 822 Number of elements of tetrahedron=2325 Number of border nodes=34

Appearance of solution area was drawn by writing Matlab program code. Meanwhile to read data of solution area (x,y,z coordinates of nodes and node numbers form tetrahedron) from file it must be saved as a file in C:MATLAB7.0.1 work.

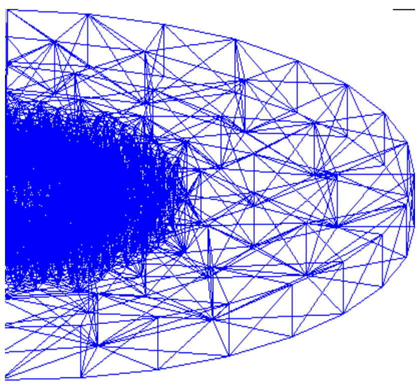


Fig.7. 3D partition of motor by Matlap

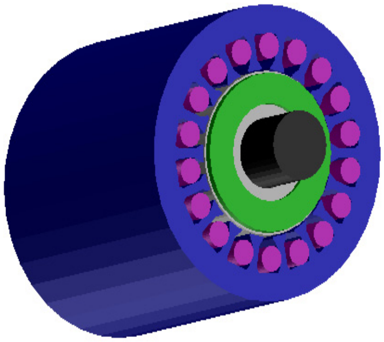


Fig.8. Appearance of asynchronous motor with Maxwell 3D

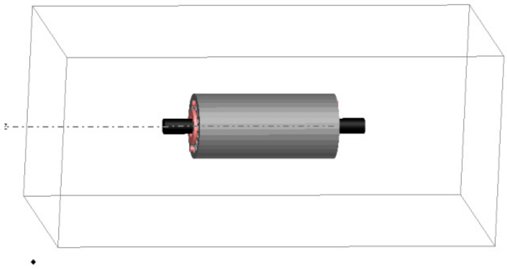


Fig.9. 3D appearance of asynchronous motor in boundary conditions

To increase the accuracy of the solution in finite element method, the number of tetrahedron reproduced in regions where the change in the potential value of vector is more. (Cupper and iron etc...) The division of certain solution area to tetrahedron elements made manually or direct computer program or both.

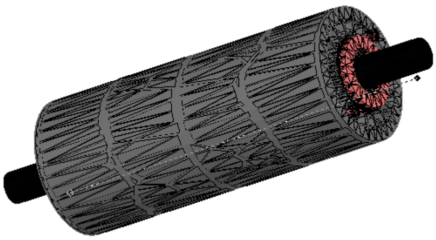
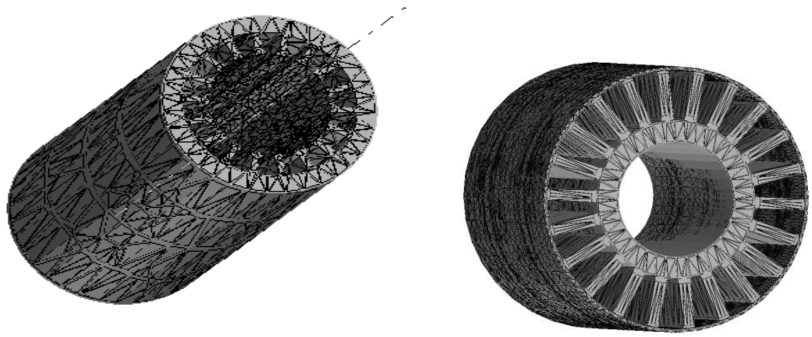


Fig.10. Automatic partition of motor



(a) (b)

Fig.11. Automatic partition of motor (a) stator and (b) rotor

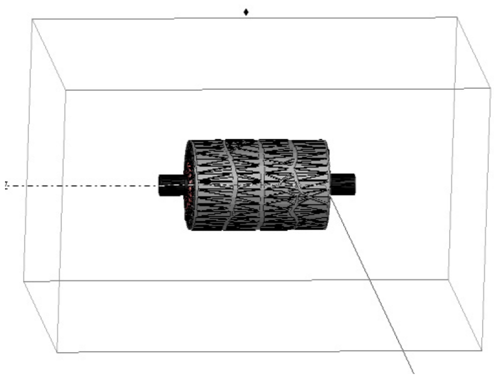
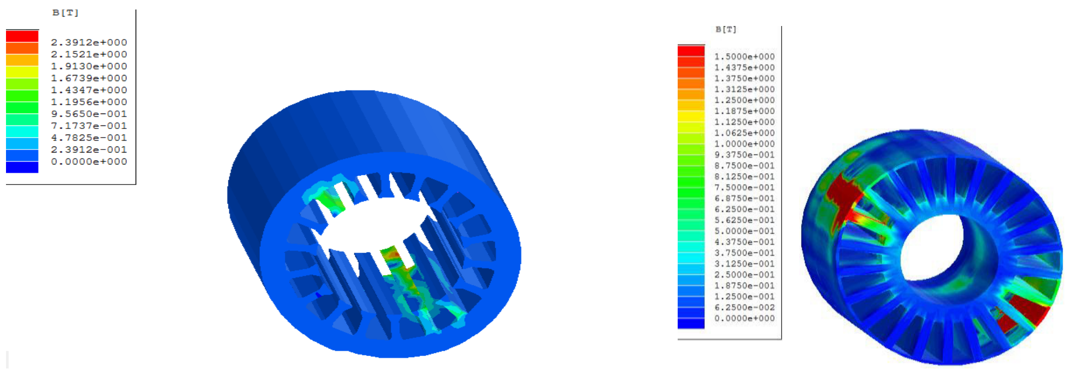


Fig.12. Automatic partitioned motor in boundary conditions



(a) (b)

Fig. 13. The flux density of one windings of stator (a) and rotor (b) of asynchronous motor (B(T))

5. Results

As a result of this analysis, asynchronous motor was drawn a partitioned into small tetrahedrons. The partitioned stator, rotor and coils of asynchronous motor were shown separately. In this study, the calculated moment value multiplied by 9 because 1/9 of motor is handled due symmetry (9*0.834). In this case, the moment was 7.5 Nm. About 0.02% of error derived from negligence in the finite element method, experimental errors in measuring device used in this study and etc. It was seen that moment increase when shift value increase. So that the analysis of motor was conducted. In conclusion, as can be understood from result using finite element method would be beneficial while designing asynchronous motor. In next studies it is aimed that finite element method will be used for comparing three-dimensional analysis of asynchronous motors by the help of Matlab software.

References

Chari, M.V.K., Silvister, P., 1970, “Finite Element Solution of Saturable Magentic Field Problems”, IEEE Transactions on Power Apparatus and Systems, Vol pas-89, No:7 (1642-1650).

Selçuk, A. H., 2003, “Lineer Asenkron Motorlarda Uç Etkilerinin Sonlu Elemanlar Yöntemiyle İncelenmesi”, Doktora Tezi, Fırat Üniversitesi, Elazığ.

Silvester, P., Cabayan, H.S., Browne, B.T., 1973, “Efficient Techniques For Finite Element Analysis Of Electric Machines”, IEEE PES Winter Meeting, New York.

Freeman, E. M., Lawther, D. A., 1973, “ Normal Force In Single Sided Linear Induction Motors”, Proc. Iee, Vol.120, No.12, Dec.

Chari, M.V.K., 1973, “Finite Element Solution Of The Eddy Current Problem In Magnetic Structures” IEEE PES Summer Meeting And EHV/UHV Conference, Vancouver, B.C. Canada.

Demirchian, K. S., Chechurin, V., Sarma, M. S., 1976, “Scalar Potential Concept For Calculating The Steady Magnetic Fields And Eddy .

Zienkiewicz, O. C., Lyness, J., Owen, D. R. J., 1977, “Three Dimensional Magnetic Field Determination Using A Scalar Potential –A Finite Element Solution”, IEEE Trans. On Mag., Vol. MAG-13, No.5, Sept.

Williamson, S., Ralph, J. W., 1982, “Finite Element Analysis For Nonlinear Magnetc Field Problems With Compşex Current Sources”, IEE Proc.Vol.129 Pt.A.No. 6 August.

Preston, T. W., Reece, A. B. J., 1982, “Solution Of 3 Dimensional Eddy Current Problems: T-Omega Method”, IEEE Trans. On Mag., Vol. MAG-18, No.2, March.

Brauer, J. R., 1982, “Finite Element Calculation Of Eddy Currents And Skin Effects”, IEEE Trans. On Mag., Vol. MAG-18, No.2, March.